Tightly Coupled Mechanistic Study of Materials in the Extreme Space Environment

2012 Space Propulsion and Power Program Review

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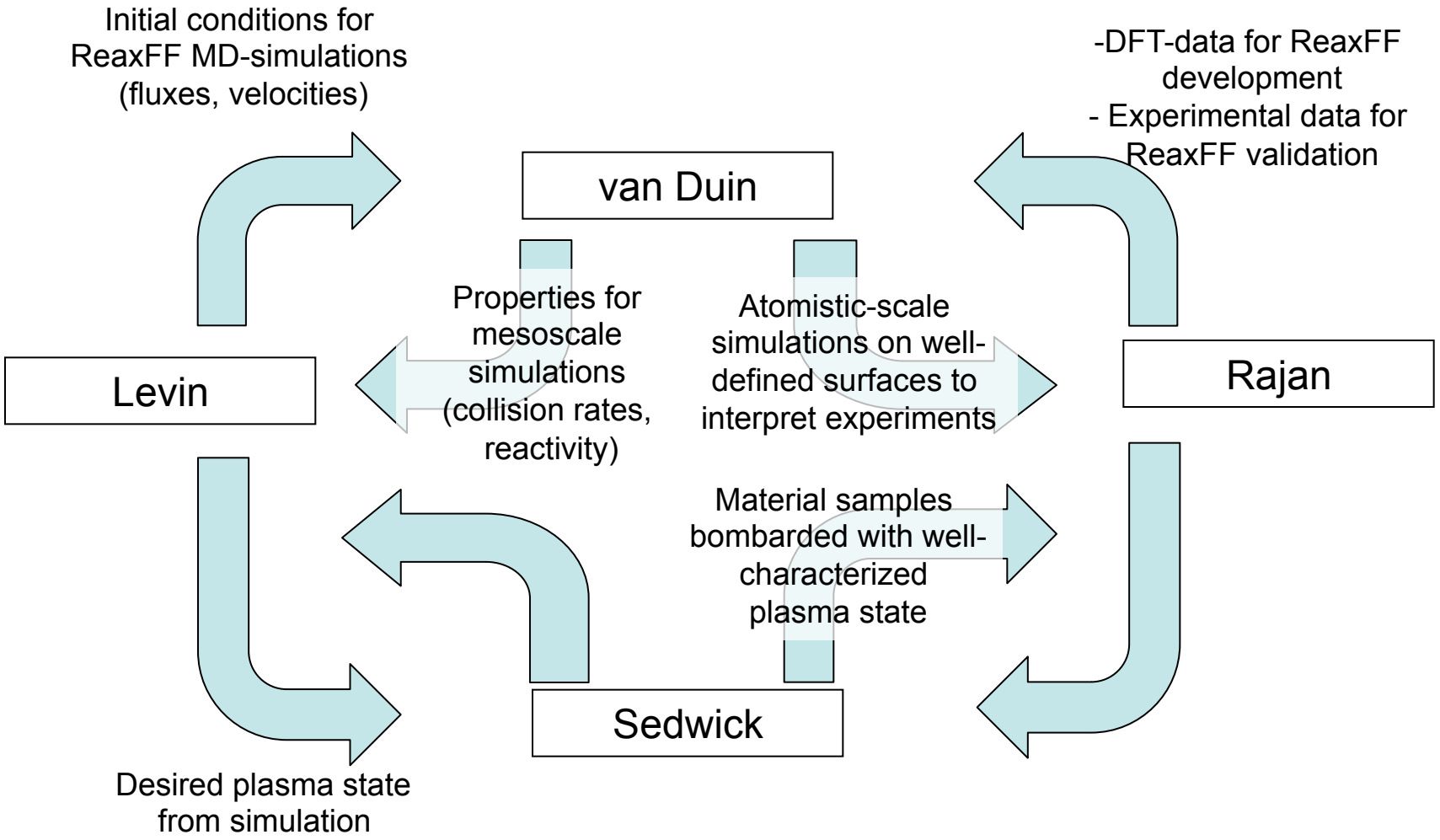
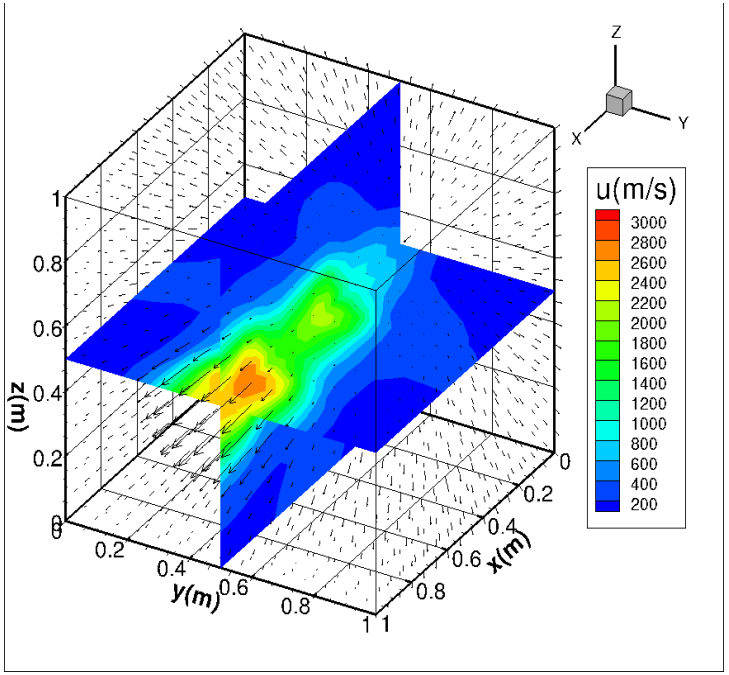
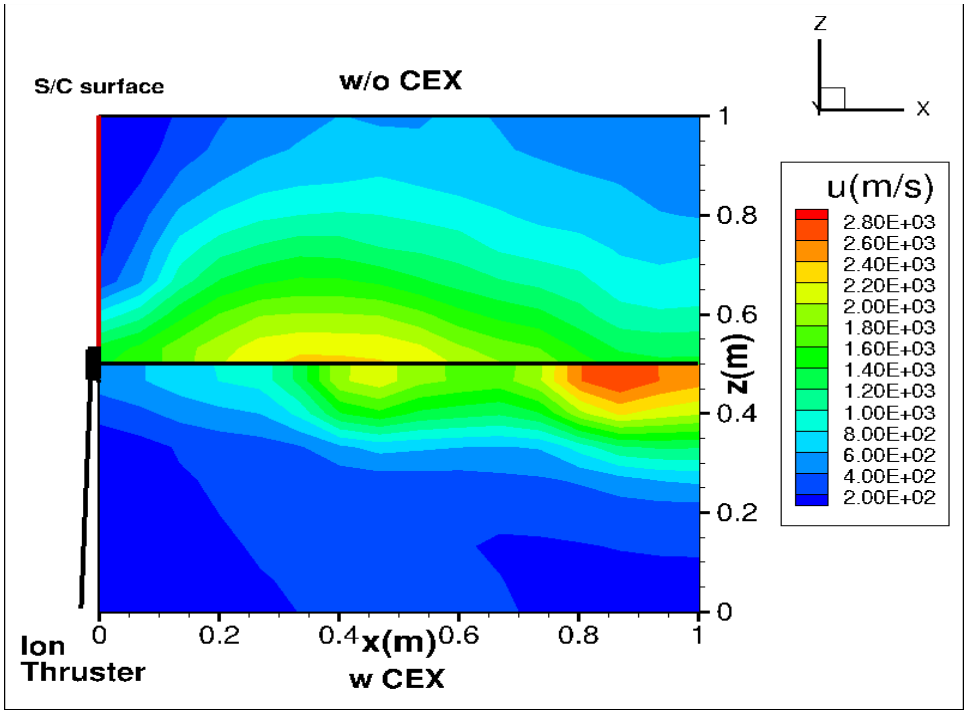
Connections in this project



D. Levin – PRELIMINARY CEX 3-D Multi-step Results

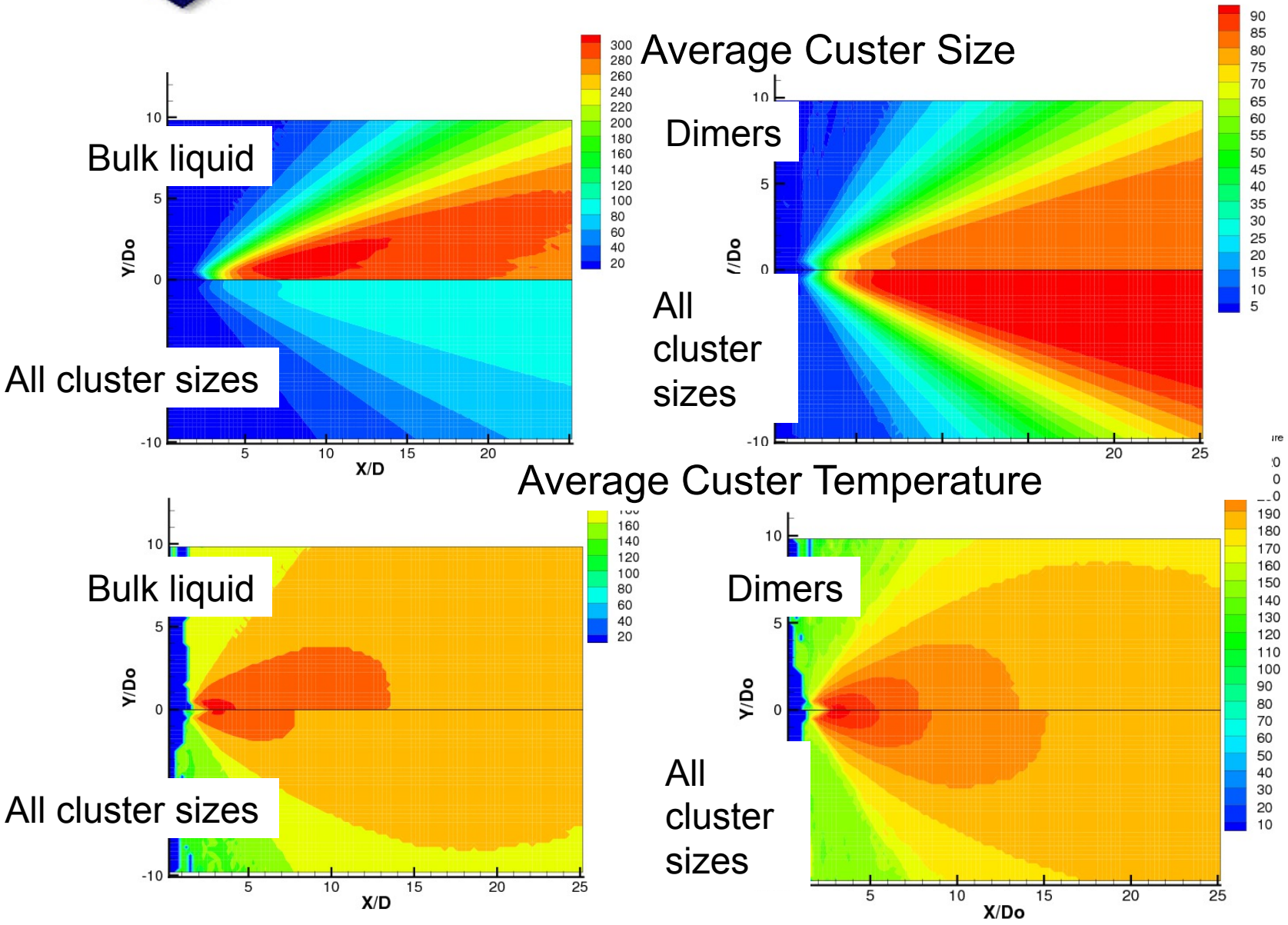




- It is apparent that cross-species interaction results in a much complex plume structure than for a pure neutral flow. The energy exchange causes neutral species to achieve much higher speeds.

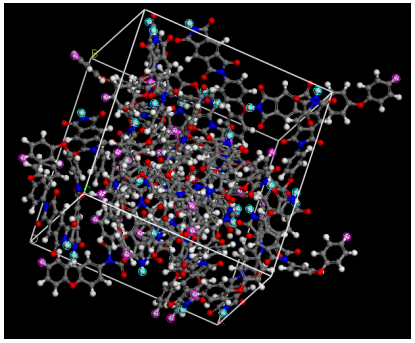
- The energy deposited by the ions into neutrals results in a lower expansion angle since directional velocity for neutrals are greatly increased when CEX reactions are present.

Sensitivity of DSMC Condensating Flows to Cluster Latent Heat Models

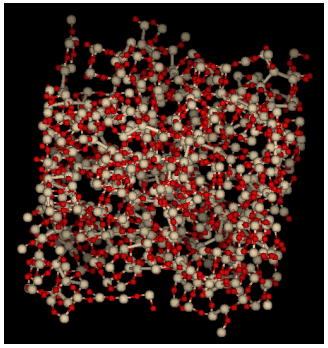


Simulations - A.C.T. Van Duin and A.Rahnamoun - ReaxFF force field

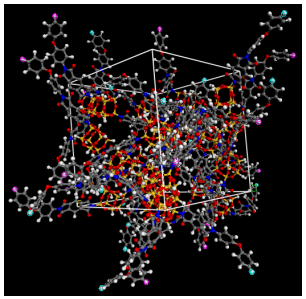
✓Kapton structure



✓Silica structure



✓POSS(Polyhedral Oligomeric Silsesquioxane) - Kapton structure mixed with silica side-chains



ReaxFF Generated Sequence of Hypervelocity Surface Impact Events

✓8 ev bombardment energy

✓Time step in the simulation is 0.1 fs

✓Frequency of high energy oxygen addition is every 2000 iterations (2ps)

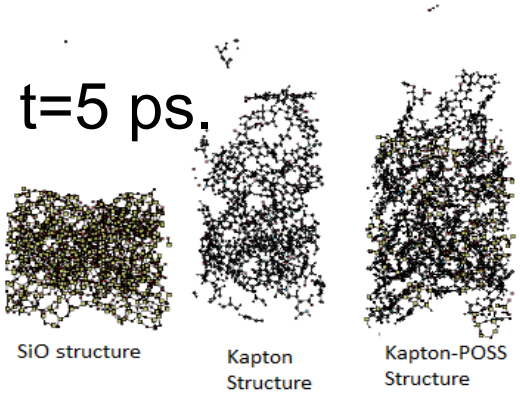
✓Disintegration rate:
Kapton > POSS >> Silica

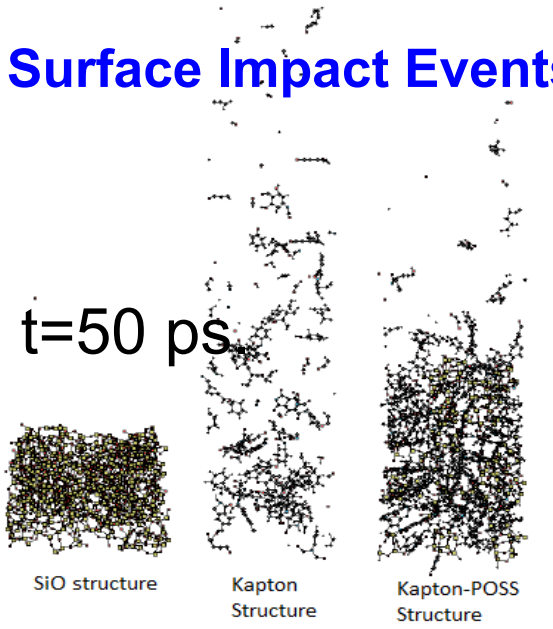
- POSS bombardment leads to silica clustering

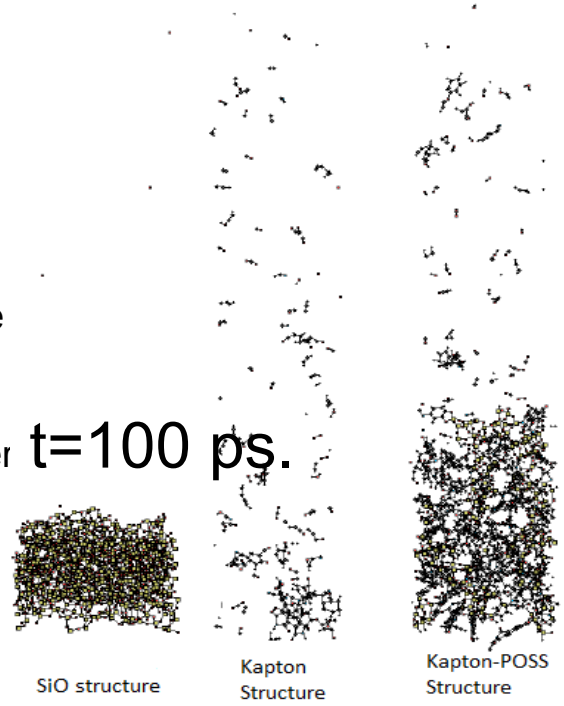
-Main Kapton decomposition products: carbon monoxide and formaldehyde

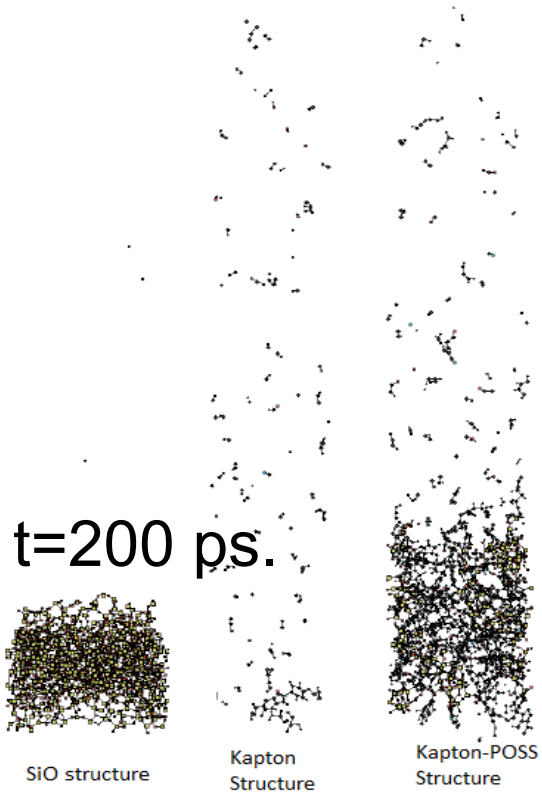
- Simulations can be used to define optimal silica addition to Kapton

- Ongoing simulations: water cluster bombardment of silica surfaces

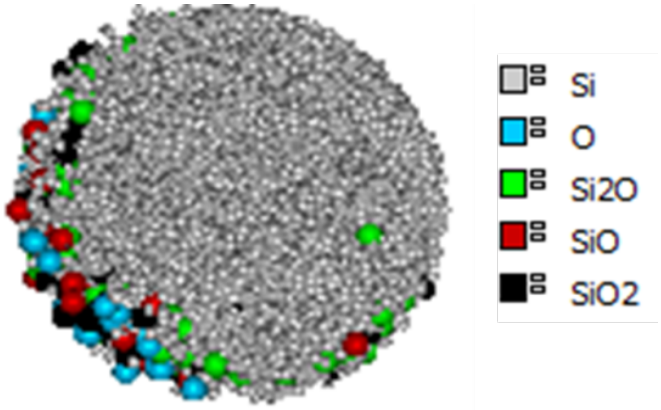


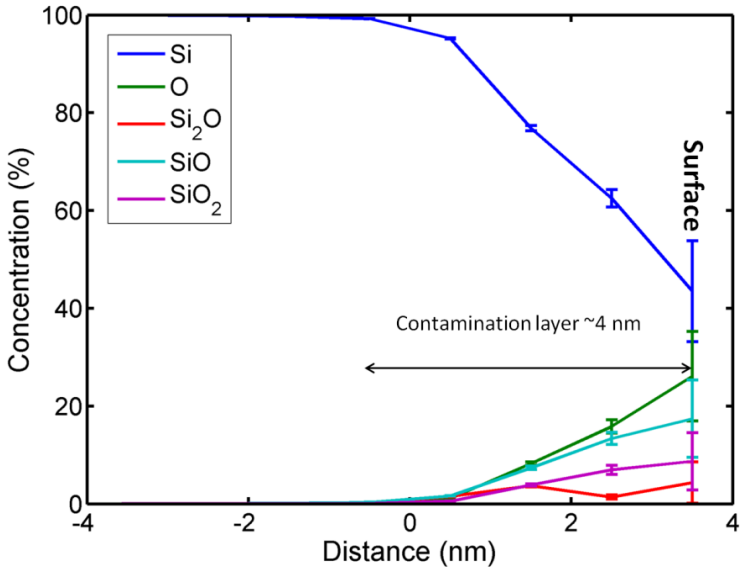






Atom probe tomography : Si / Silica/ Oxygen Reactions



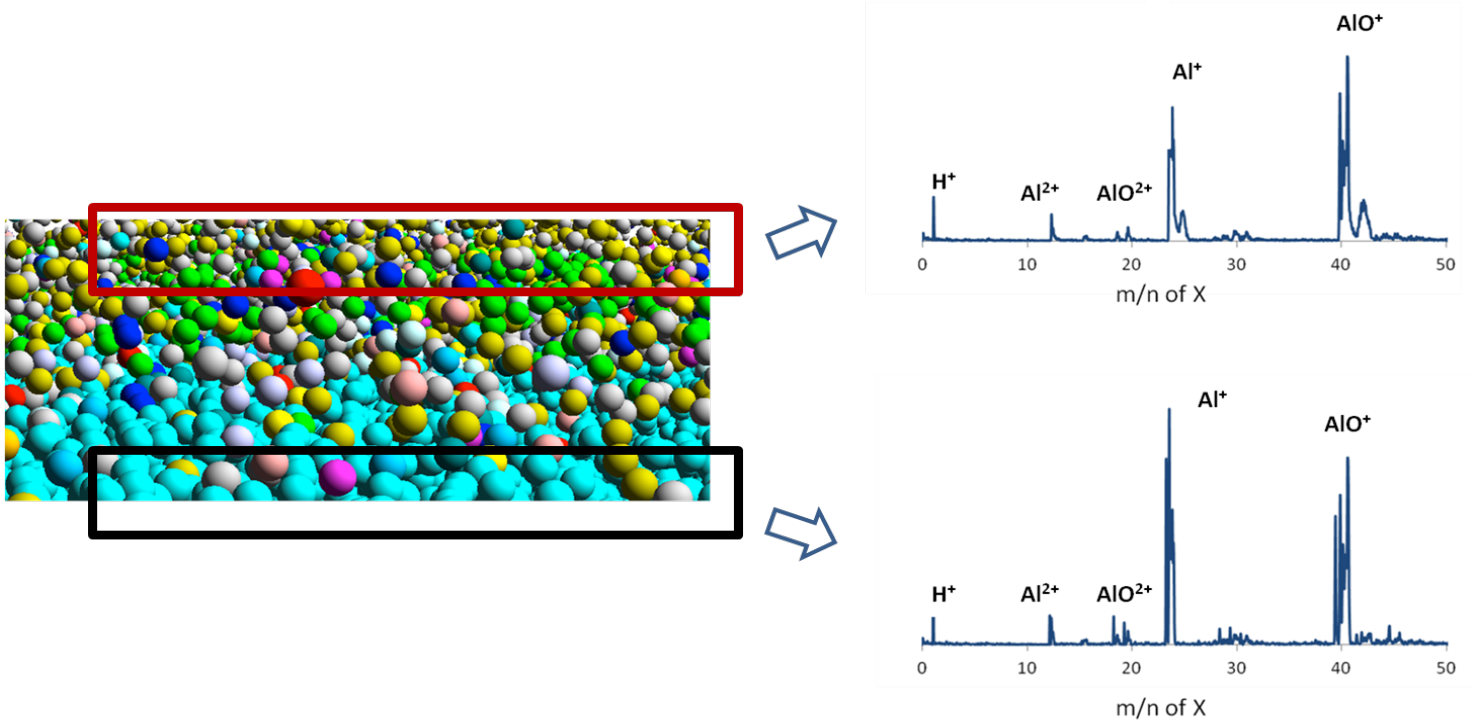


- A cross section image of the specimen showing the degradation of silicon due to silicon-oxygen reaction at the surface was taken.

- The concentration profile across the Si-Oxide interface measuring surface chemistry and the diffusion of gas into the material was made.

- The ratio of O:Si-O compounds decreases with diffusion distance, implying that the metal-gas reactions and subsequent bond strengths are strongest at the metal-gas interface, while the resulting surface atoms are more weakly bonded to material.

Atom probe tomography: Al / Alumina/ Oxygen Reactions



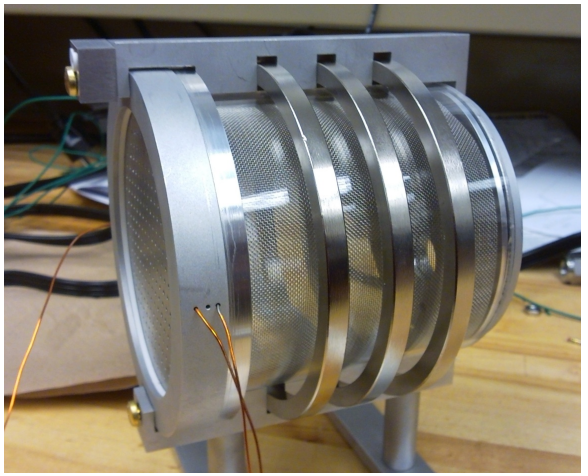
➢Measurement of pair wise interactions between Al and other atoms / compounds at the atomic scale.

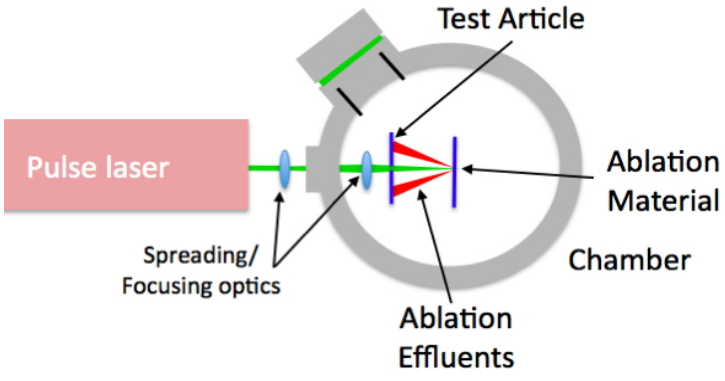
➢The top spectra describes the compounds and corresponding valencies that degrade concurrent with Al^+ atom in the alumina region at the interface; the bottom spectra is the same except in the Al region near the interface.

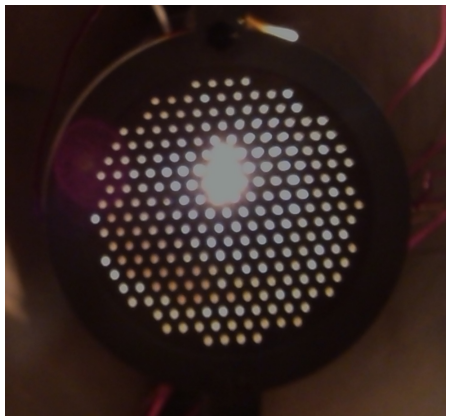
➢This map allows us to understand the complexity of the chemical states and identify the differences in bonding and inter-atomic interactions. The differences in the spectra represent changes in material degradation between phases at the metal surface, and describe the strength of inter-atomic interactions and mechanism for gas-solid reaction.

Material bombardment with well-characterized plasma state – Plasma Sources

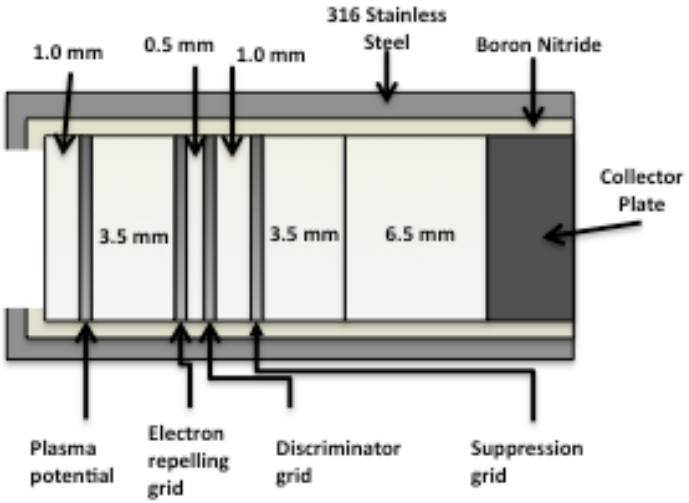
- Ion Engine Simulator – Completed, under test
  - Characteristic ion energy/density and neutral density
  - Also can be used for validation of CEX modeling
- Gen-II IonEtch sputter ion Gun – Available for testing
  - Microwave source supports reactive species
  - Energies up to 5 keV
- Dusty Plasma Source – Currently under design
  - AFOSR Funded DURIP
  - Will use laser ablation to generate both atoms and particulates/droplets from solids/liquids

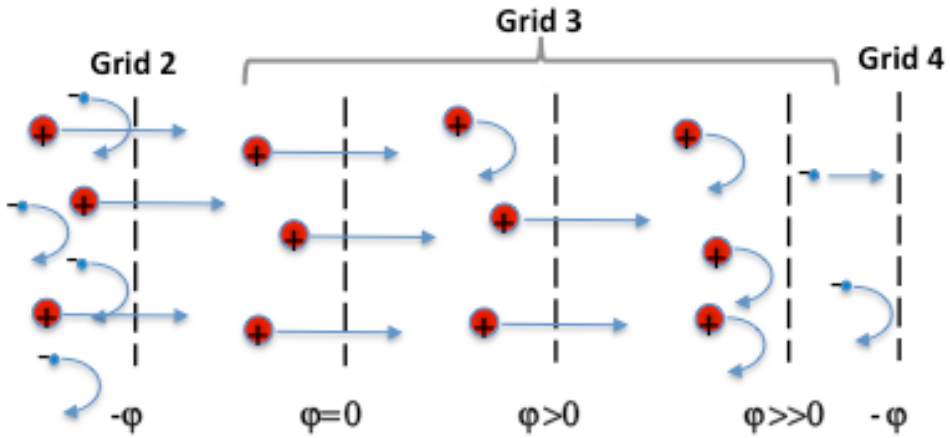




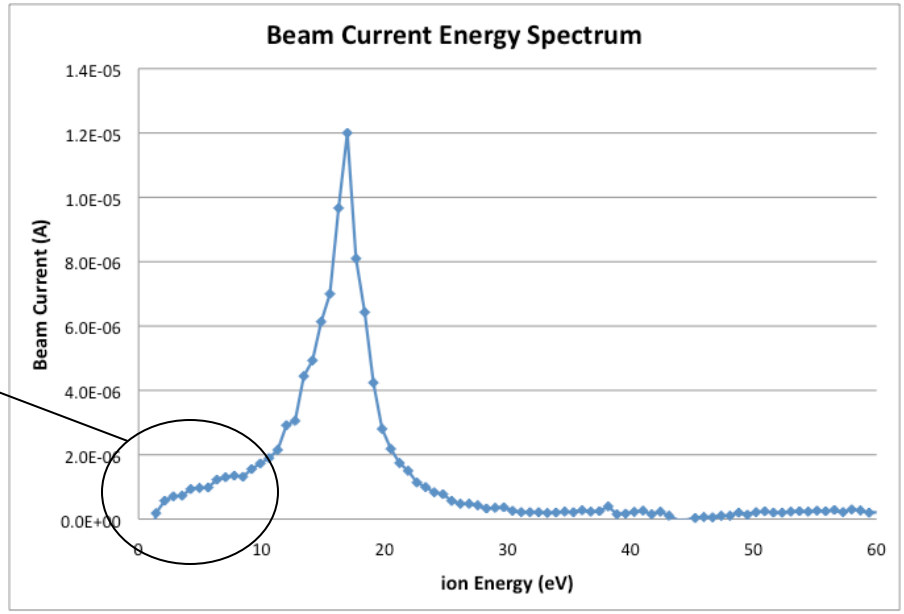


Ion energy spectrum analysis – Retarding Potential Analyzer





- RPA used to determine beam energy spectrum
- Spatially resolving ion energy distribution can characterize CEX reactions
  - Lower energy ions appear farther from the exit plane and centerline
- For dusty plasma source, TOF will also be employed to determine charge-to-mass distribution as well



First Batch of Silicon tip coupons being shipped to UMD from Iowa State

- Each coupon contains 36 (6x6) individual pre-sharpened micro-tips
- Each tip is sharpened to a point less than 50 nm in diameter and is 100 microns (+/-20) in height
- Coupon are 3 mm x 7 mm and come on a gel pack

Prior to testing with coupons, small blanks will be used and analyzed with an SEM

- This will help to establish minimum and maximum exposure times for coupon testing

Coupons will be temporarily mounted to a backing plate during testing and then returned to the gel pack